Scale Up of SECA Based Fuel Cell Technology for Large Scale Hybrid Power Systems

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Outline

Background

Methodology

Results:
- System Design
- Performance
- Cost

Conclusions/Implications for Fuel Cell Hybrids

Application of stack modules to larger capacity applications is key to SECA's strategy.

- Develop ~5 kW SOFC modules for mass-customization
- Small-capacity applications (1-5 stacks), including:
  - Residential / light commercial DG
  - Auxiliary power for vehicles
  - Remote power
- Larger capacity applications:
  - Large commercial / industrial DG (10-1000s stacks)
  - Sub-station level DG and central generation (synergy with Vision21 program)
- How to scale-up to hundreds of kW or MW?

SECA wanted to understand the issues involved in scaling up to 100-kW to 1-MW systems.

Objective: to assess whether and how SECA stack modules can be integrated into a 250 kWe plant.

- Develop thermodynamic design, system lay-out, performance estimate, and cost estimates
- SOFC stack:
  - Use 5 kW planar SOFC modules *
  - Combine into super-modules
  - *Implications for electric interconnection of the units?*
  - *Implications for manifolding?*
- Balance of plant:
  - Determine scale and integration
  - *Impact of scale-up on system performance and cost?*
- Simple-cycle operation

We developed a conceptual design for a 250-kW$_e$ distributed generation system SOFC.

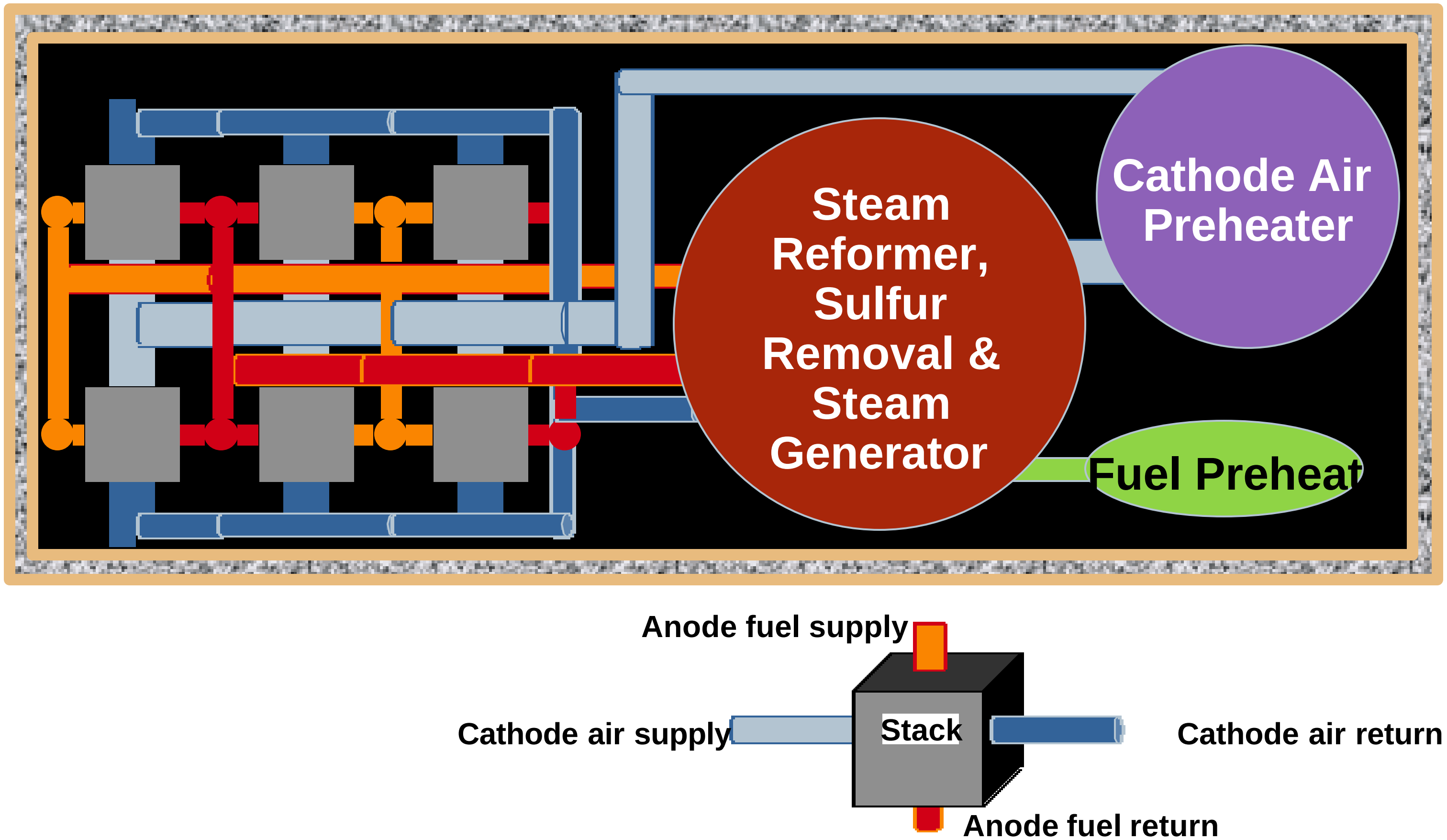
System Specifications	Assumptions: Stack	Assumptions: Balance of Plant
◆ System output: 250-kW$_e$ net @ 380V 3-phase AC ◆ Electrical system efficiency >50% (LHV) ◆ Availability >99% ◆ $T_{Surface}$ < 45°C ◆ High production volume (10,000 units per year)	◆ 5 kW modules ◆ Cell voltage 0.7 V ◆ Anode-supported technology ◆ T_{stack} 650 - 800°C ◆ Power density 0.6 W/cm^2 ◆ 85% fuel utilization per pass in fuel cell	◆ Water supplied (no water recovery) ◆ Steam reformer ◆ Natural gas fuel, (20" H_2O gauge)

The current program will develop much of the information needed to analyze fuel cell hybrid technology strategies:

- System schematics/layouts of simple cycle architectures
- Reactant flow conditions at each point in the cycle:
  - temperature levels
  - flow rates
  - reactant chemistries
  - pressure levels (for near atmospheric systems)
- Performance model which can be modified to pressurized operation and integration with hybrid hardware

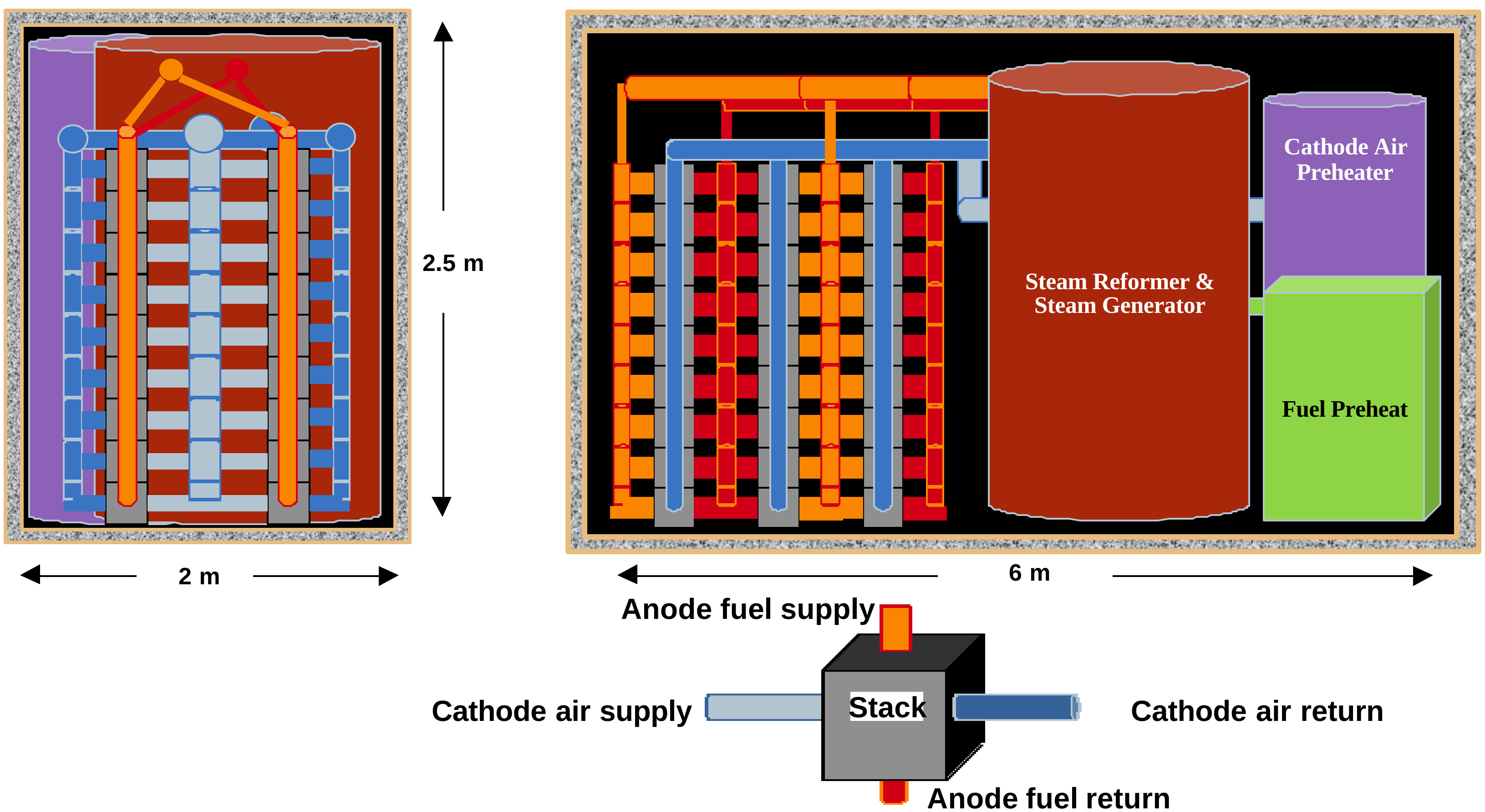
We developed a conceptual system design, to assess implications of manifolding and interconnection.

Hot Box Configuration with Rectangular Cross-Flow Cells: Top View



We limited integration to the reformer and air preheaters, to maintain reasonable access.

250-kW System Configuration: Side Views

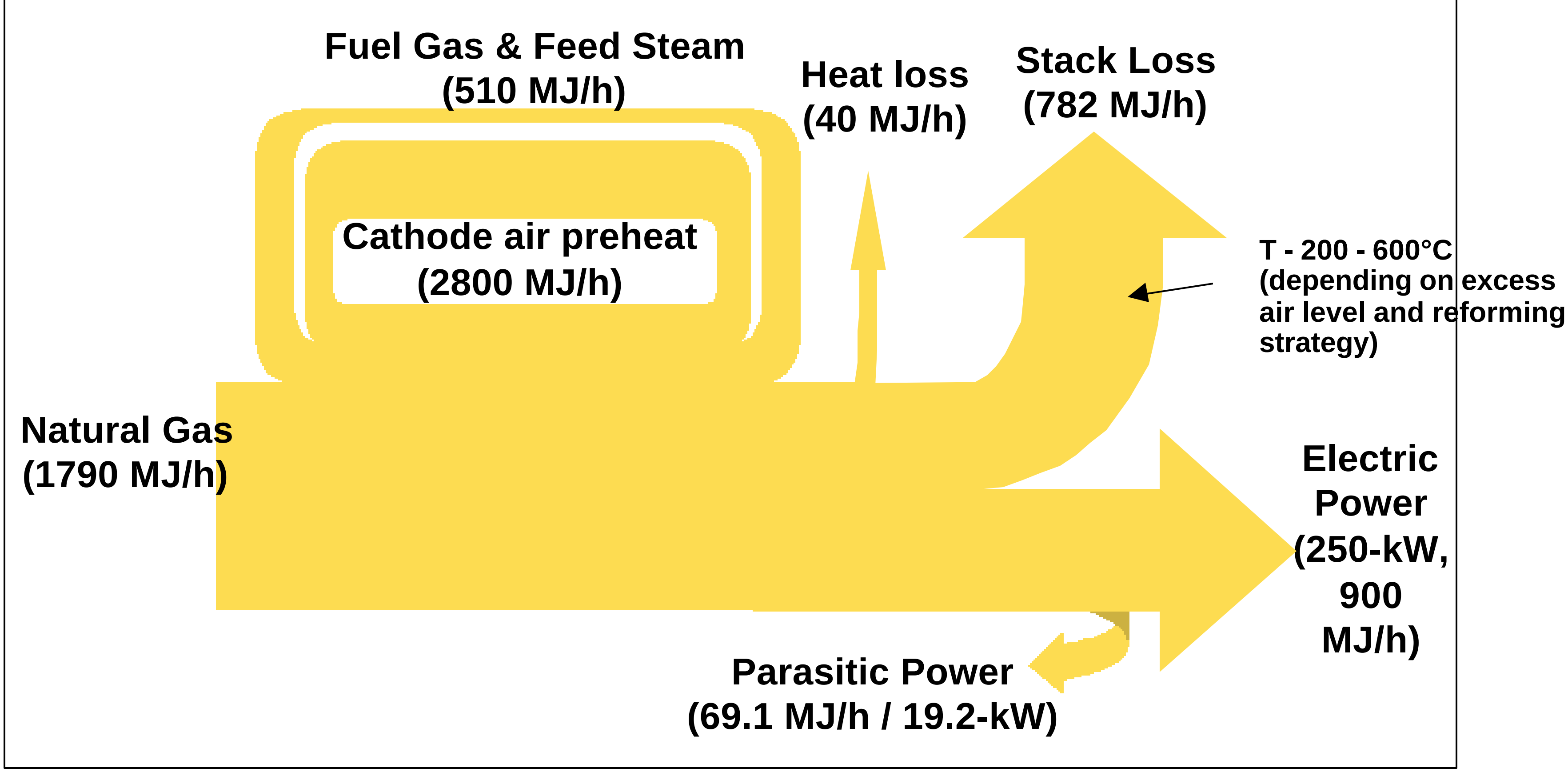


With careful thermal integration, a system efficiency of 51% can be achieved in simple-cycle configuration.

Anode Fuel Utilization	85%
Fuel Cell, Cell Voltage	0.7 V
Stack Temperature	650 - 800ºC
Cathode Excess Air (for Cooling)	7.7 times
Blower Pressure	1.17 bar
Exhaust Temperature	177ºC
Parasitic Loads	19 kW
Required Fuel Cell Gross Power Rating	269 kW
Resultant Overall Efficiency	51%

Extensive energy recovery from hot exhaust gas is critical to achieving high system efficiency.

Energy Flow in 250-kW SOFC system (all on LHV)



Integration of SECA modules can result in cost-effective high-performance larger-scale systems.

- Integration of over fifty stacks appears feasible:
  – Several manageable configurations identified
  – Manifolding and interconnection losses acceptable
  – Cost savings in balance of plant
- High-efficiency simple-cycle plant appears feasible, and result in attractive cost ($500 - $600/kW equipment cost)
  – Lower-efficiency, lower-cost systems may be more flexible in operation and preferable in some situations
- Cost and performance would be attractive
  – In the 250 kW system, benefits of economy of scale are largely offset by lower production volumes compare to 5 kW systems

The 250 kW simple cycle design is a good starting point for consideration of fuel cell hybrid options -- the issues will include:

- The impact on stack design of pressurized operation.
- The optimal integration of reactant gas flows to (for example, use of unspent reactants in anode gas stream)
- The sensitivity of hybrid system performance to stack operating temperatures
- The impact of internal reforming and excess air levels on system level optimization
- The lowest cost design strategies for 1+ MW capacity systems -- example: multiple 250 kW systems combined with a single turbine/compressor